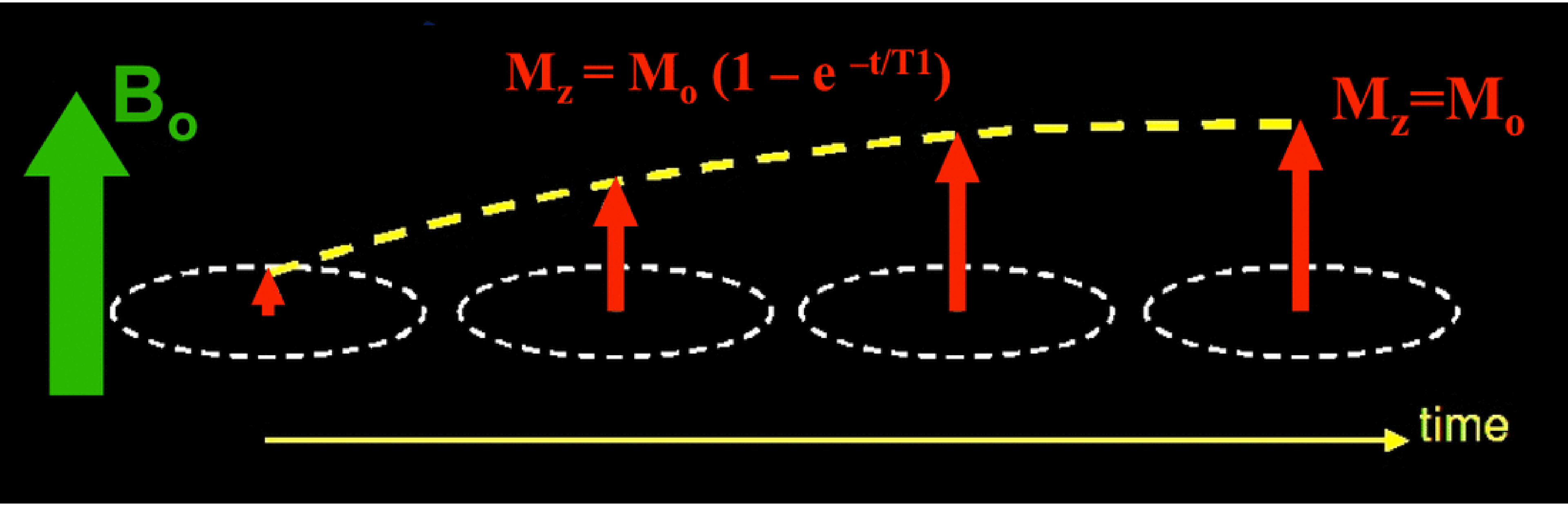
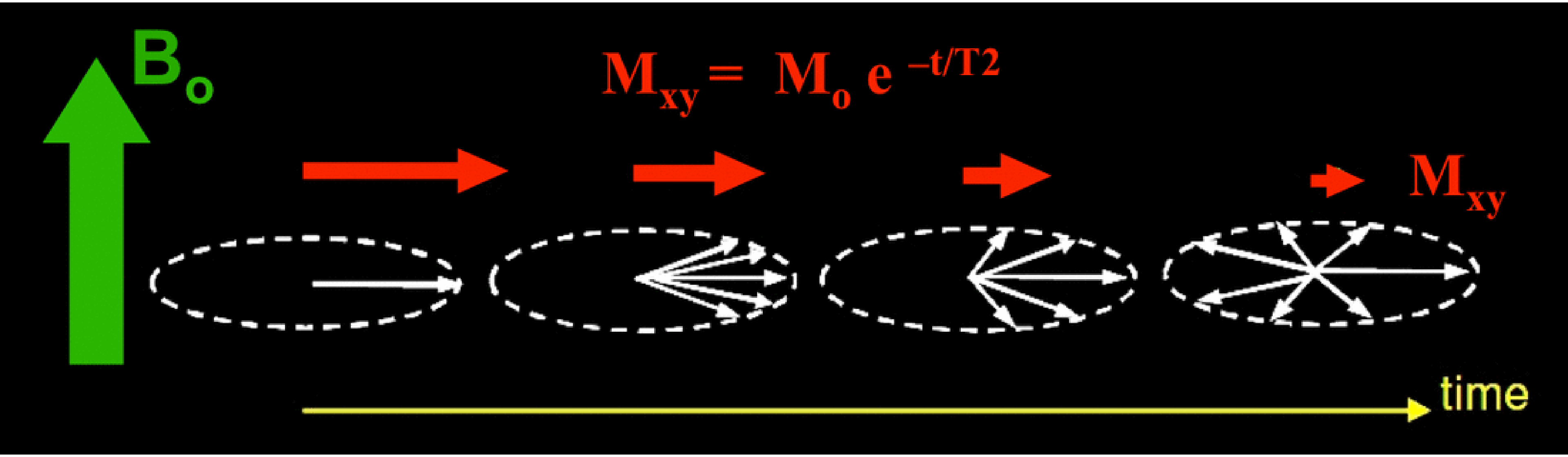
Nuclear Magnetic Resonance

T_1 relaxation is the process by which the net magnetization (**M**) grows/returns to its initial maximum value parallel to $\mathbf{B_o}$
a.k.a. ***longitudinal relaxation***, ***thermal relaxation*** and ***spin-lattice relaxation***. Energy dissipating.



Nuclear Magnetic Resonance

T_2 relaxation: transverse components of magnetization decay or dephase, a.k.a. ***transverse relaxation*** or ***spin-spin relaxation***



What might cause such dephasing?

Fluctuating B, any process causing T1 relaxation also results in T2 relaxation

$$\frac{1}{T_2} = \frac{1}{2T_1} + \frac{1}{T_2'}$$

Pure dephasing

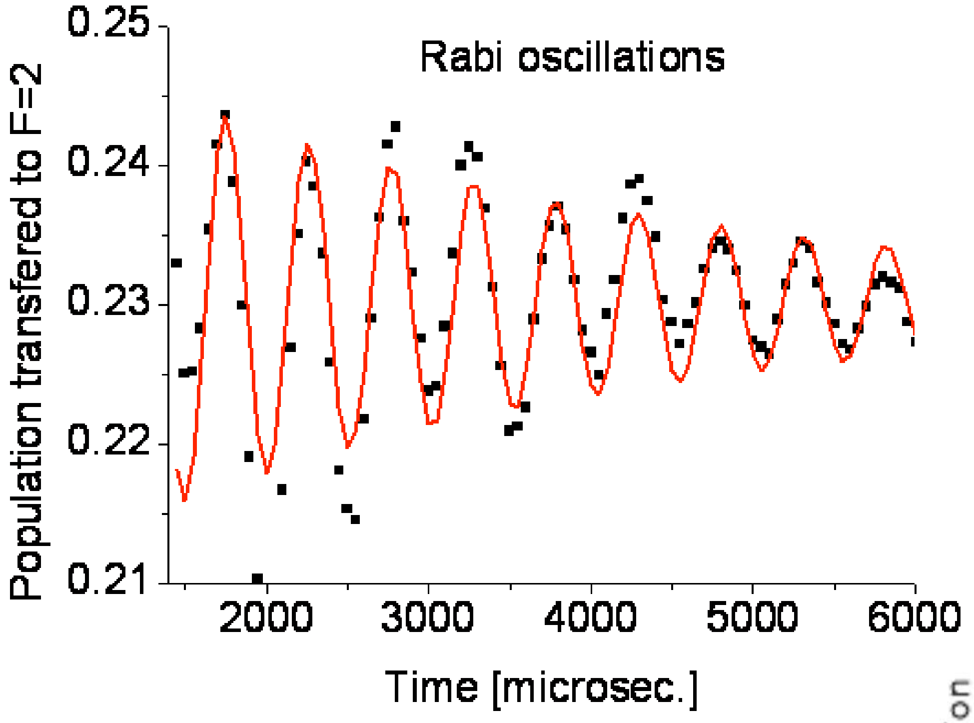
Often $T_2' \ll T_1$

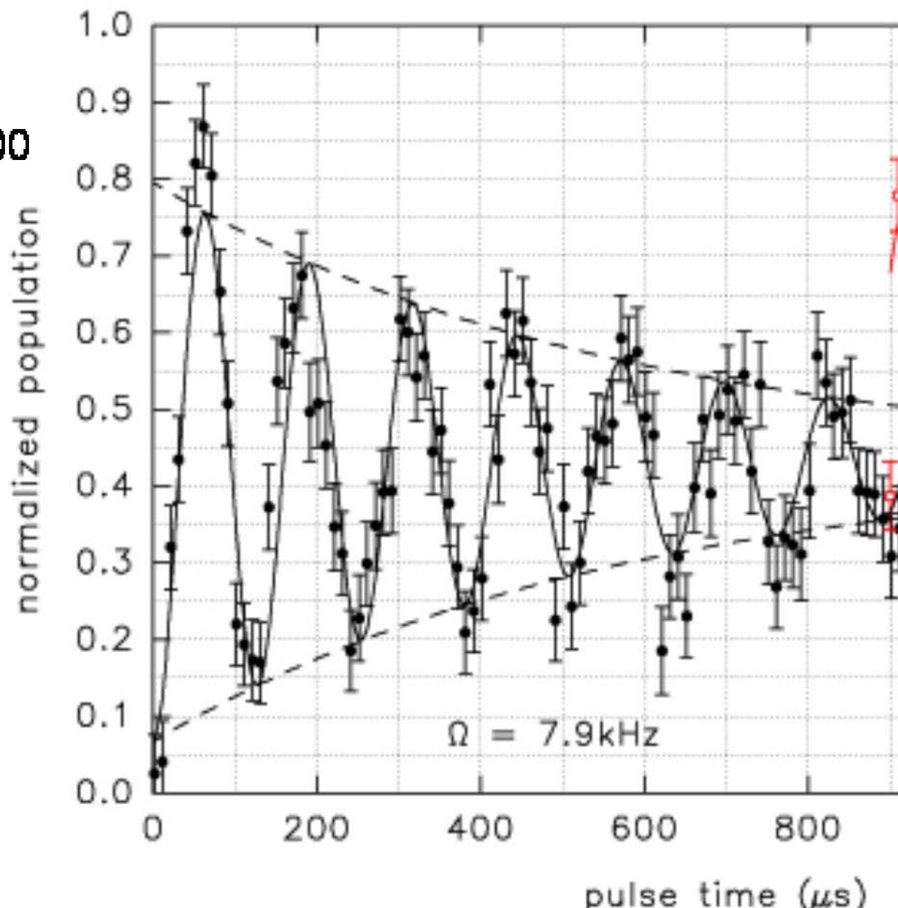
Nuclear Magnetic Resonance

T_2 relaxation: transverse components of magnetization decay or dephase, a.k.a. ***transverse relaxation*** or ***spin-spin relaxation***

- T2 = "true" T2, caused by atomic/molecular interactions
- T2* = "observed" T2, reflecting true T2 as well as magnetic field inhomogeneities
- $1/T2^* = 1/T2_{true} + 1/T2_{inhom}$

$$T_2^* < T_{2,true}$$


Rabi oscillations
Population transfered to F=2
0.25
0.24
0.23
0.22
0.21
2000
3000
4000
5000
6000
Time [microsec.]


normalized population
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Ω = 7.9kHz
0
200
400
600
800
pulse time (μs)

On-Demand Single Photons with High Extraction Efficiency and Near-Unity Indistinguishability from a Resonantly Driven Quantum Dot in a Micropillar

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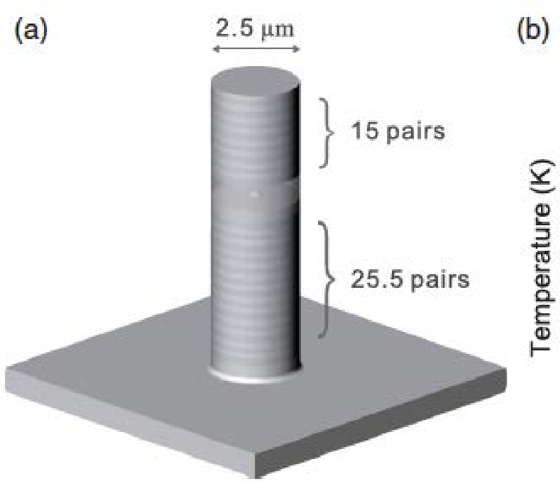
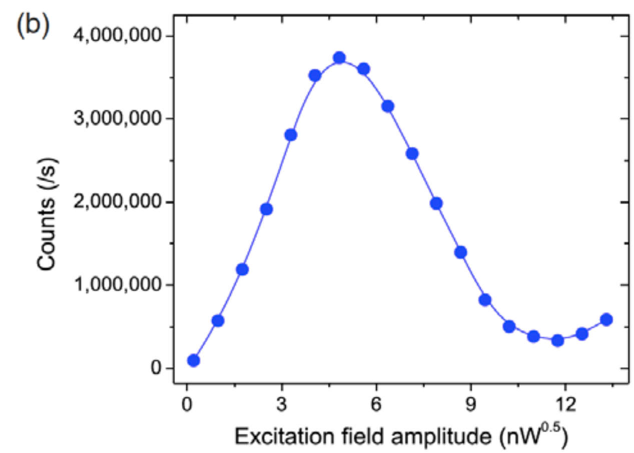
Scalable photonic quantum technologies require on-demand single-photon sources with *simultaneously* high levels of purity, indistinguishability, and efficiency. These key features, however, have only been demonstrated separately in previous experiments. Here, by *s*-shell pulsed resonant excitation of a Purcell-enhanced quantum dot-micropillar system, we deterministically generate resonance fluorescence single photons which, at π pulse excitation, have an extraction efficiency of 66%, single-photon purity of 99.1%, and photon indistinguishability of 98.5%. Such a single-photon source for the first time combines the features of high efficiency and near-perfect levels of purity and indistinguishabilty, and thus opens the way to multiphoton experiments with semiconductor quantum dots.





Rabi oscillation (resonance fluorescence)
→ peak excitation for 24 nW laser power

How does a pi-pulse de-excite an atom more quickly than spontaneous decay?

The Zeno's paradox in quantum theory

Misra, B.; Sudarshan, E. C. G.

Journal of Mathematical Physics 18, pp. 756-763 (1977).

Time evolution of unstable quantum states and resolution of Zeno's paradox

Chiu, Sudarshan and Misra, Phys Rev. D **16**, 520 (1977)

What are Quantum Jumps? Richard J Cook, Physica Scripta **T21**, 49 (1988)

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Quantum Zeno effect

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(Received 12 October 1989)

The quantum Zeno effect is the inhibition of transitions between quantum states by frequent measurements of the state. The inhibition arises because the measurement causes a collapse (reduction) of the wave function. If the time between measurements is short enough, the wave function usually collapses back to the initial state. We have observed this effect in an rf transition between two $^{9}Be^{+}$ ground-state hyperfine levels. The ions were confined in a Penning trap and laser cooled. Short pulses of light, applied at the same time as the rf field, made the measurements. If an ion was in one state, it scattered a few photons; if it was in the other, it scattered no photons. In the latter case the wave-function collapse was due to a null measurement. Good agreement was found with calculations.

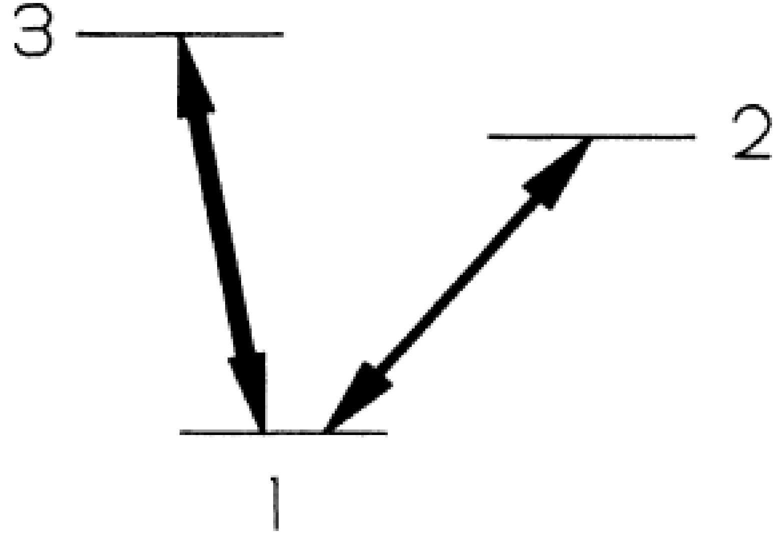


FIG. 1. Energy-level diagram for Cook's proposed demonstration of the quantum Zeno effect.

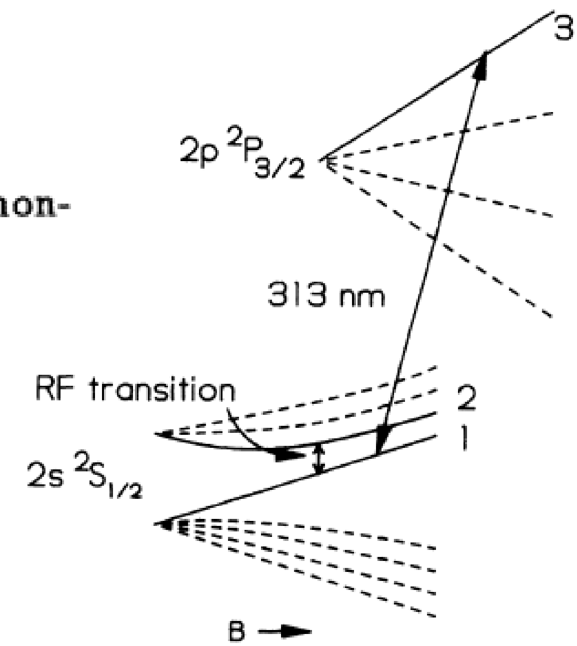


FIG. 2. Diagram of the energy levels of $^9Be^+$ in a magnetic field B. The states labeled 1, 2, and 3 correspond to those in Fig. 1 .

TABLE I. Predicted and observed values of the 1 → 2 and 2 → 1 transition probabilities for different values of the number of measurement pulses n. The uncertainties of the observed transition probabilities are about 0.02. The second column shows the transition probabilities that result from a simplified calculation, in which the measurement pulses are assumed to have zero duration and in which optical pumping is neglected.

		1 → 2 transition	
n	$\frac{1}{2}[1-\cos^n(\pi/n)]$	Predicted	Observed
1	1.0000	0.995	0.995
2	0.5000	0.497	0.500
4	0.3750	0.351	0.335
8	0.2346	0.201	0.194
16	0.1334	0.095	0.103
32	0.0716	0.034	0.013
64	0.0371	0.006	−0.006

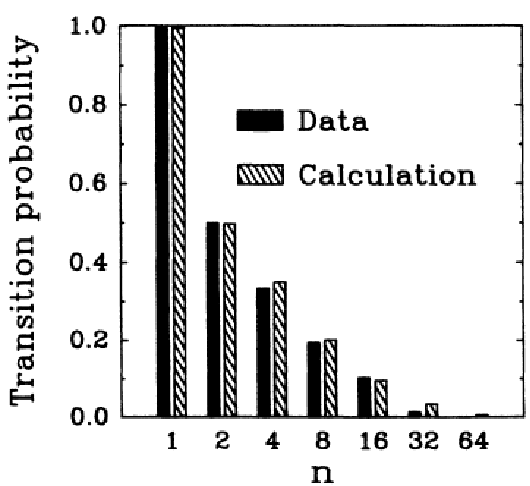


FIG. 3. Graph of the experimental and calculated 1 → 2 transition probabilities as a function of the number of measurement pulses n. The decrease of the transition probabilities with increasing n demonstrates the quantum Zeno effect.

How many photons need to be detected during the probe pulse to collapse the state?

How many photons need to be *emitted* during the probe pulse to collapse the state?

TABLE I. Predicted and observed values of the 1 → 2 and 2 → 1 transition probabilities for different values of the number of measurement pulses n. The uncertainties of the observed transition probabilities are about 0.02. The second column shows the transition probabilities that result from a simplified calculation, in which the measurement pulses are assumed to have zero duration and in which optical pumping is neglected.

n	$\frac{1}{2}[$	2 → 1 transition Predicted	Observed
1		0.999	0.998
2		0.501	0.496
4		0.365	0.363
8		0.217	0.209
16		0.118	0.106
32		0.073	0.061
64		0.080	0.075

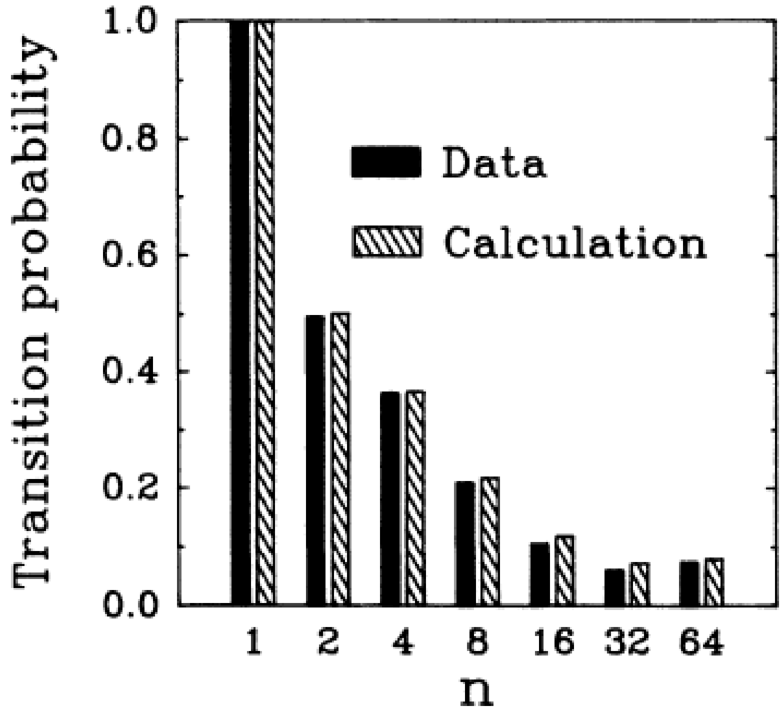
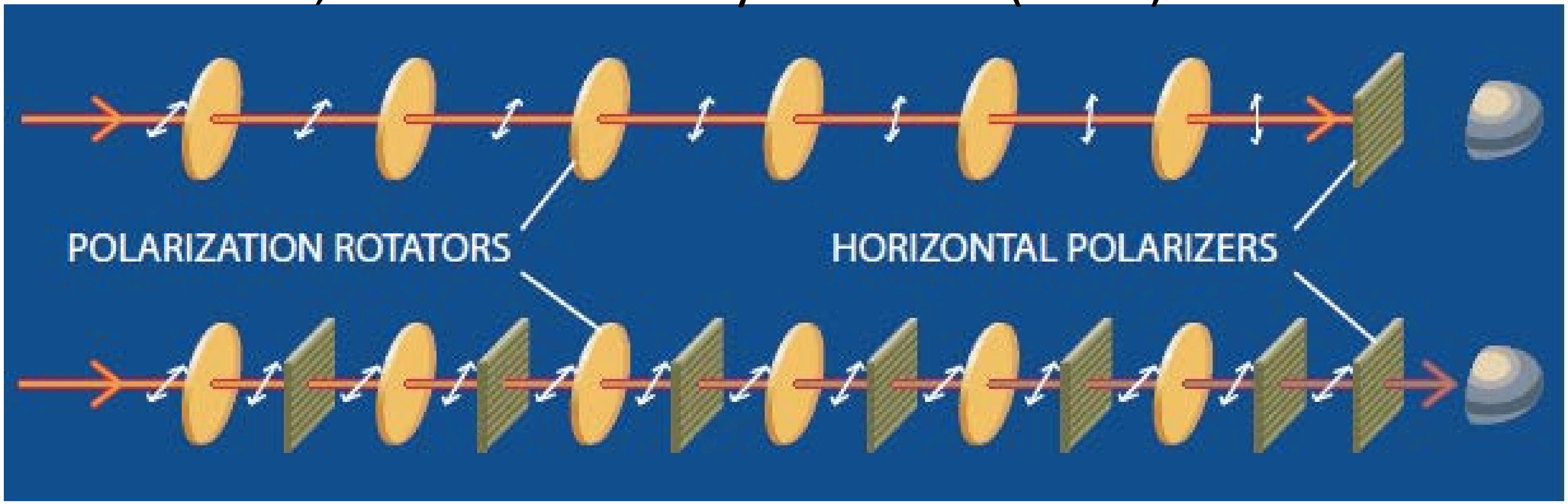


FIG. 4. Graph of the experimental and calculated 2 → 1 transition probabilities as a function of the number of measurement pulses n. The transition probabilities for $n = 32$ and $n = 64$ are higher than the corresponding ones for the 1 → 2 transition because of an optical pumping effect discussed in the text.

Asher Perez, Amer. Journ. Phys. **48** 931 (1980)



$$P_{trans} = \left[\cos^2\left(\frac{\pi}{2N}\right)\right]^N \xrightarrow[N\to\infty]{} 1$$